Introduction and Project Overview

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GlueX Spokesperson

Presentations

- Introduction and Project Overview (40'+20')
  - Curtis Meyer, Carnegie Mellon
- Focusing Box Prototype Studies (30'+15')
  - Mike Williams, MIT
- Mechanical Design, Integration and Transport (30'+15')
  - Matt Shepherd, Indiana University
- Project Management, Cost, and Schedule (40' + 20')
  - Justin Stevens, Jefferson Lab

Outline

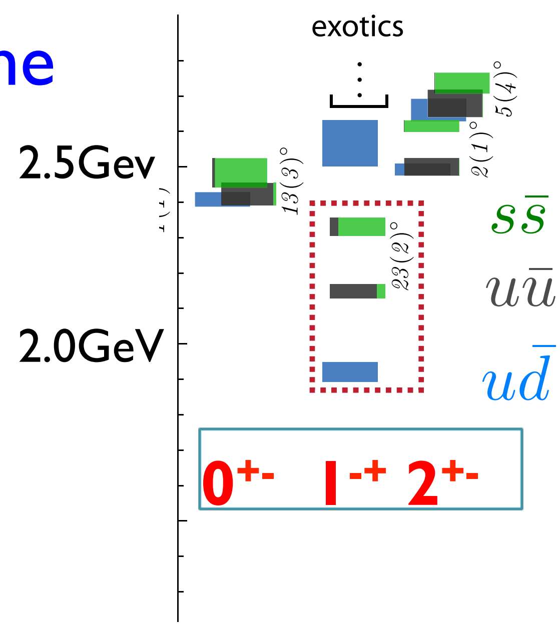
- The GlueX physics program.
- The GlueX Experiment.
- The Need for forward kaon identification.
- Summary

Quantum Chromo Dynamics

QCD describes the interactions of quarks and gluons and should predict the spectrum of bound-state baryons (qqq) and mesons ($q\bar{q}$).

There should also be mesons in which the gluonic field contributes directly to the J^{PC} quantum numbers of the states --- hybrid mesons. Some are expected to have ``exotic" quantum numbers.

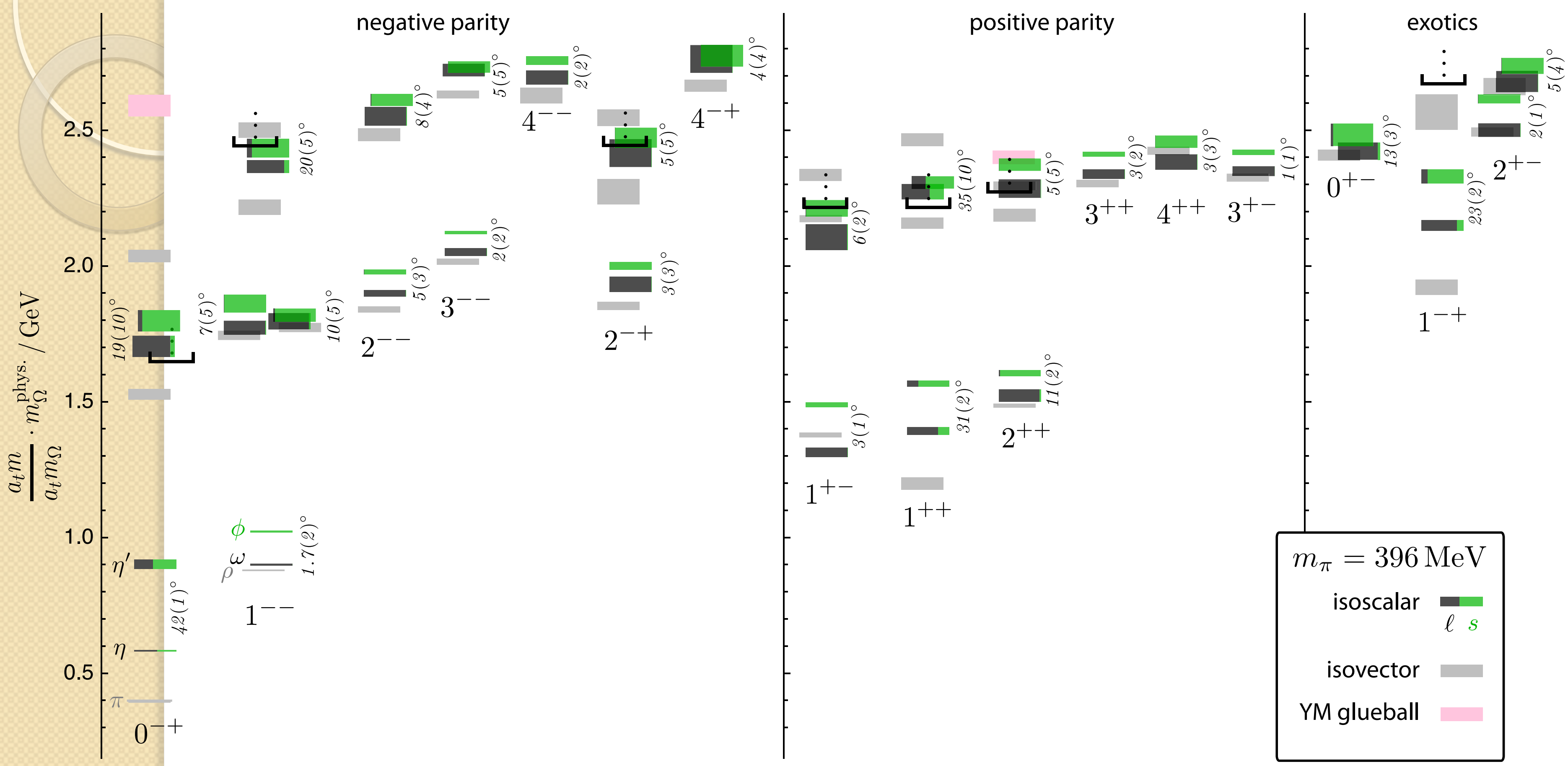
Lattice QCD calculation of the light-quark meson spectrum.



``Constituent gluon": $J^{PC} = 1^{+-}$
mass of 1-1.5 GeV.
The lightest hybrid nonets
1^{--}, (0^{-+}, 1^{-+}, 2^{-+})

Lattice QCD

Light-quark Mesons (u,d,s)

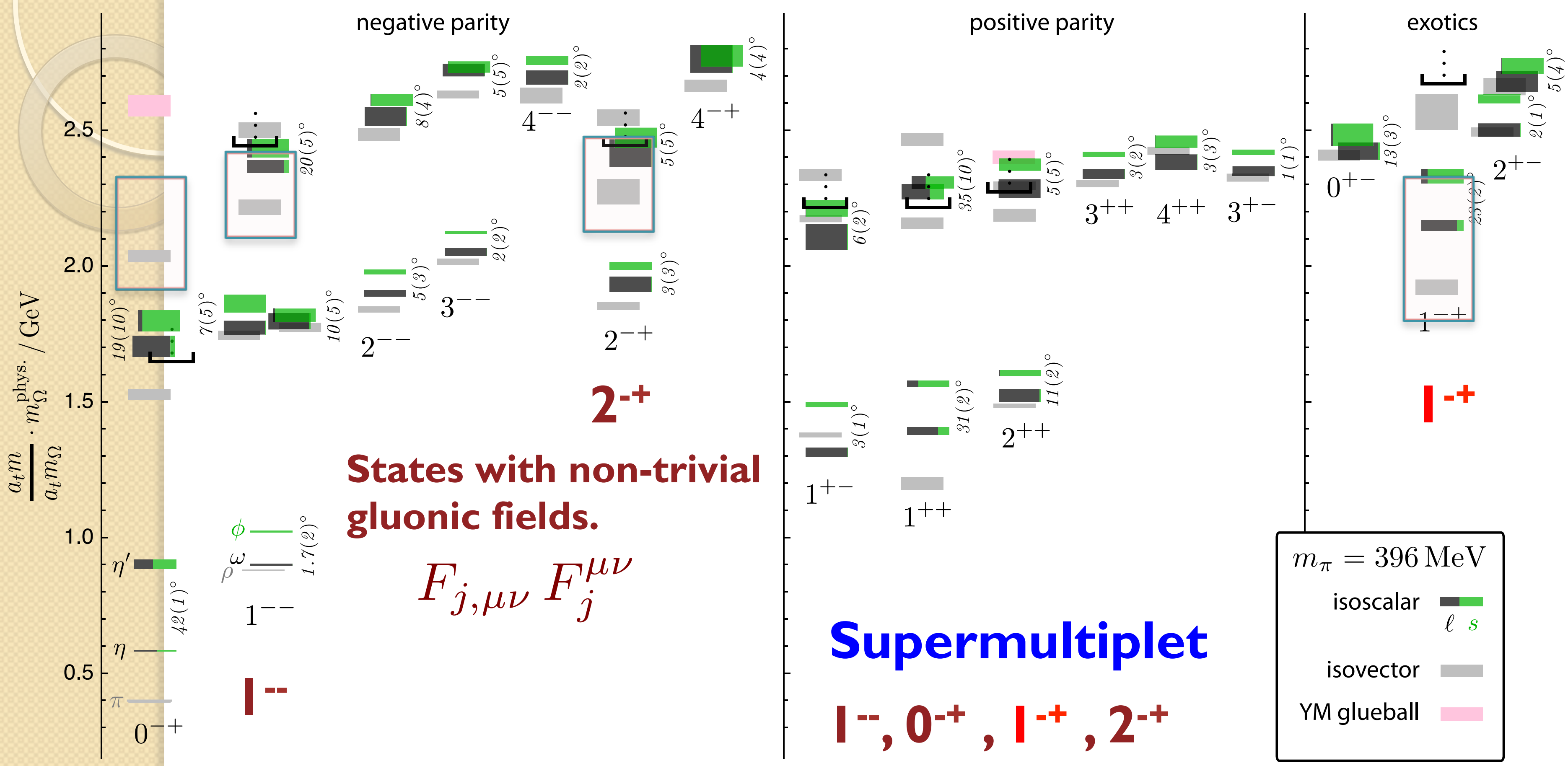


$$\frac{1}{\sqrt{2}}\left(u\bar{u} - d\bar{d}\right) \qquad \frac{1}{\sqrt{2}}\left(u\bar{u} + d\bar{d}\right) \qquad \left(s\bar{s}\right)$$

Dudek, *et. al*, Phys. Rev. D**83**, 111502 (2011)

Lattice QCD

Light-quark Mesons (u,d,s)



2^{-+}

States with non-trivial gluonic fields.

$F_{j,\mu\nu} F_j^{\mu\nu}$

1^{-+}

1^{--}

0^{-+}

Supermultiplet

1^{--}, 0^{-+} , 1^{-+} , 2^{-+}

$$\frac{1}{\sqrt{2}}(u\bar{u} - d\bar{d}) \qquad \frac{1}{\sqrt{2}}(u\bar{u} + d\bar{d}) \qquad (s\bar{s})$$

Nonet Mixing

Experimental results on mixing:

$$J^{PC} = 0^{-+} : \pi, \eta, \eta', K : \theta = -11.5^\circ$$
$$J^{PC} = 1^{--} : \rho, \omega, \phi, K^* : \theta = 38.7^\circ$$
$$J^{PC} = 1^{+-} : b_1, h_1, h'_1, K_{1B} : \theta = 34^\circ$$
$$J^{PC} = 1^{++} : a_1, f_1, f'_1, K_{1A} : \theta = 13^\circ$$
$$J^{PC} = 2^{++} : a_2, f_2, f'_2, K^*_2 : \theta = 28^\circ$$
$$J^{PC} = 3^{--} : \rho_3, \omega_3, \phi_3, K^*_3 : \theta = 31^\circ$$

Ideal Mixing: **θ = 35.3°**

$|u\bar{u} + d\bar{d} >$ $|s\bar{s} >$

Lattice QCD suggests the lightest hybrids don't have ideal mixing:

0^{-+} ground state and radial
1^{--} $^3D_1$ ground state.
1^{++} ground state
1^{-+} exotic

Measure through decay rates:

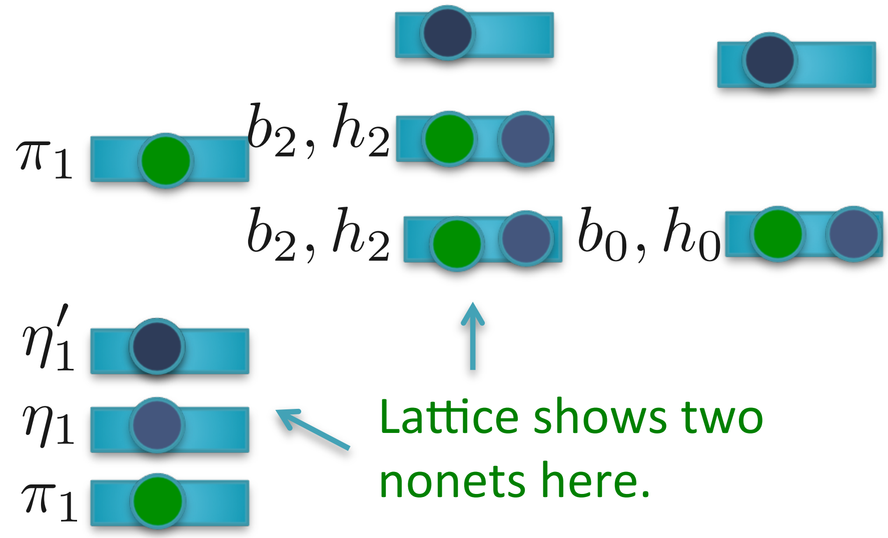
$f_2(1270) \rightarrow KK / f_2(1270) \rightarrow \pi\pi \sim 0.05$
$f'_2(1525) \rightarrow \pi\pi / f'_2(1525) \rightarrow KK \sim 0.009$

GlueX needs to observe the $s\bar{s}$ & $l\bar{l}$ states
See their decays to strange final states.

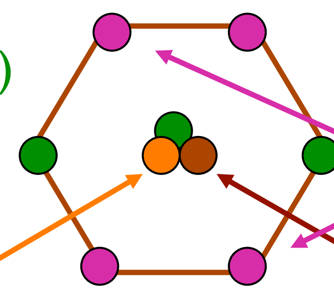
QCD Exotics

Lattice QCD suggests 5 nonets of mesons with exotic quantum number:

1 nonet of 0^{+-} exotic mesons
2 nonets of 1^{-+} exotic mesons
2 nonets of 2^{+-} exotic mesons



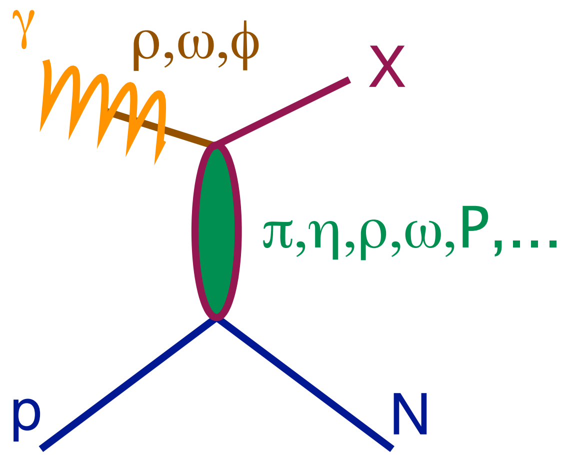
Experimental evidence exists for π_1 states.



``Constituent gluon" behaves like $J^{PC} = 1^{+-}$ with a mass of 1-1.5 GeV

The lightest hybrid nonets:
1^{--}, (0^{-+}, 1^{-+}, 2^{-+})

Photoproduction Mechanisms



Simple quantum number counting for production: **$(I^G)J^{PC}$ up to L=2**

P = Pomeron exchange

ρπ,ρω	→	π_1
ωω,ρρ	→	η_1
ωω,ρρ,φω	→	η'_1
ρP	→	b_0
ωP	→	h_0
ωP, φP	→	h'_0
ωπ,ρη,ρP	→	b_2
ρπ,ωη,ωP	→	h_2
ρπ,ωη,φP	→	h'_2

ρπ is charge-exchange only

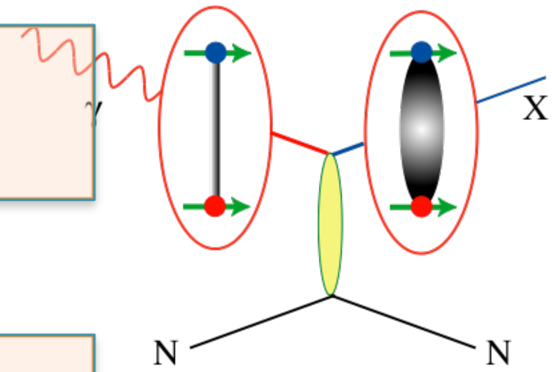
Can couple to all the lightest exotic hybrid nonets through photoproduction and VMD.

Linear polarization is a filter on the naturality of the exchanged particle.

Decay Modes of Exotic Hybrids

$\pi_1 \rightarrow \pi\rho$, πb_1, πf_1, $\pi\eta'$, ηa_1

$\eta_1 \rightarrow \eta f_2$, $a_2\pi$, ηf_1, $\eta\eta'$, $\pi(1300)\pi$, $a_1\pi$,
$\eta_1' \rightarrow K^*K$, $K_1(1270)K$, $K_1(1410)K$, $\eta\eta'$



$b_2 \rightarrow \omega\pi$, $a_2\pi$, $\rho\eta$, $f_1\rho$, $a_1\pi$, $h_1\pi$, $b_1\eta$

$h_2 \rightarrow \rho\pi$, $b_1\pi$, $\omega\eta$, $f_1\omega$
$h'_2 \rightarrow K_1(1270)K$, $K_1(1410)K$, K_2^*K, $\phi\eta$, $f_1\phi$

$b_0 \rightarrow \pi(1300)\pi$, $h_1\pi$, $f_1\rho$, $b_1\eta$

$h_0 \rightarrow b_1\pi$, $h_1\eta$
$h'_0 \rightarrow K_1(1270)K$, $K(1460)K$, $h_1\eta$

Early Reach **With Statistics** **Hard**

Models suggest narrower states are in the spin-1 and spin-2 nonets, while the spin-0 nonets are broad.

Hybrid kaons do not have exotic QN's

We need good kaon identification separate the mixed states

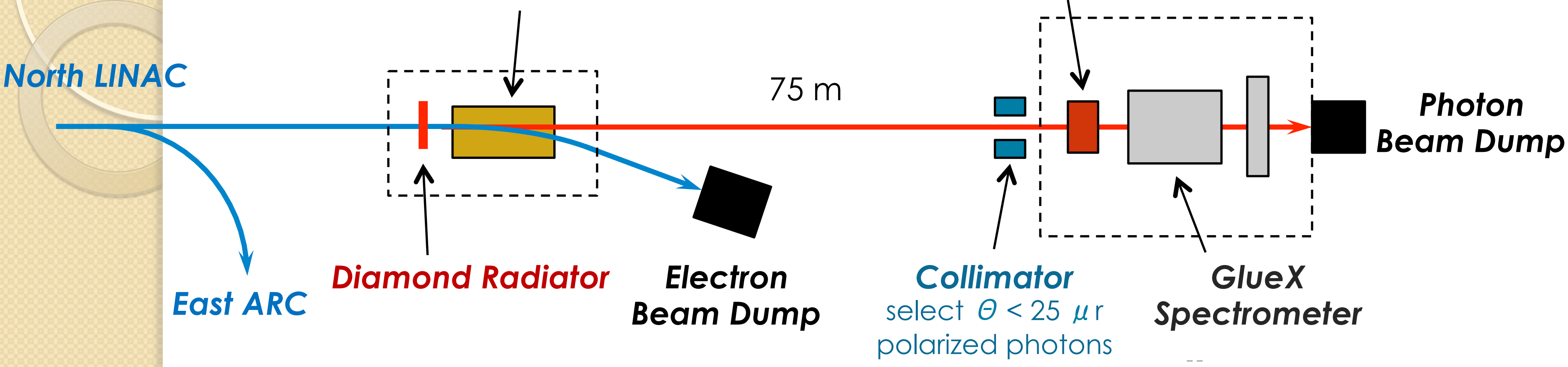
GlueX Analysis

- Reconstruct exclusive final states.
- Kinematical fitting of events possible.
- Event identification relies on global analysis.
- All detectors contribute to event analysis.
- In GlueX physics, pions outnumber kaons by a factor of 10.
- Better suppression of pions in kaonic final states is needed for the full GlueX program.

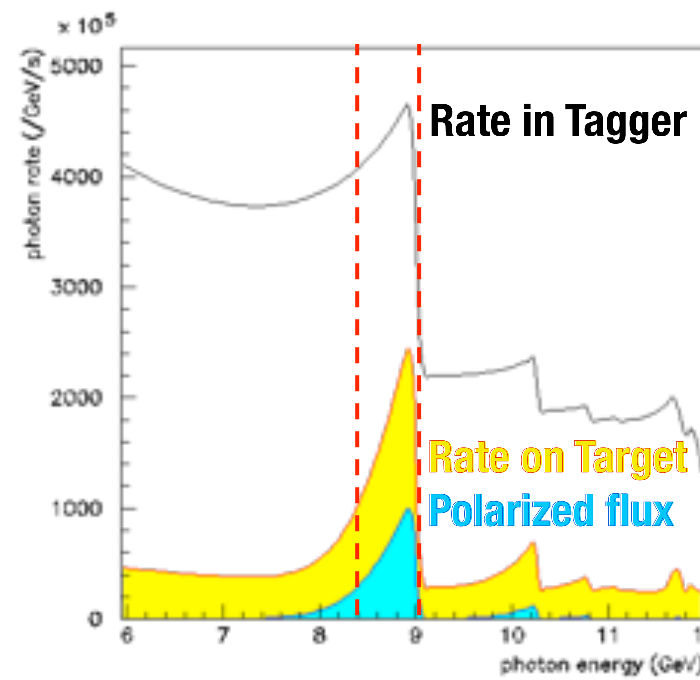
GlueX Analysis

- An amplitude analysis is used to identify partial waves (of given spin and parity) and ultimately exotic hybrids.
- The sensitivity of the amplitude analysis is approximately at the level of the background contamination in the sample.
- Kaon identification is a crucial handle to reduce backgrounds in kaonic final states where misidentified pions dominate the background.

The GlueX Experiment



- 12 GeV e^- beam up to 2.2 μA.
- Linearly polarized photons ($P_\gamma \approx 40\%$) from coherent bremsstrahlung on diamond radiator
- Design intensity of 10^8 γ/s in coherent peak (E_γ = 8.4-9 GeV)

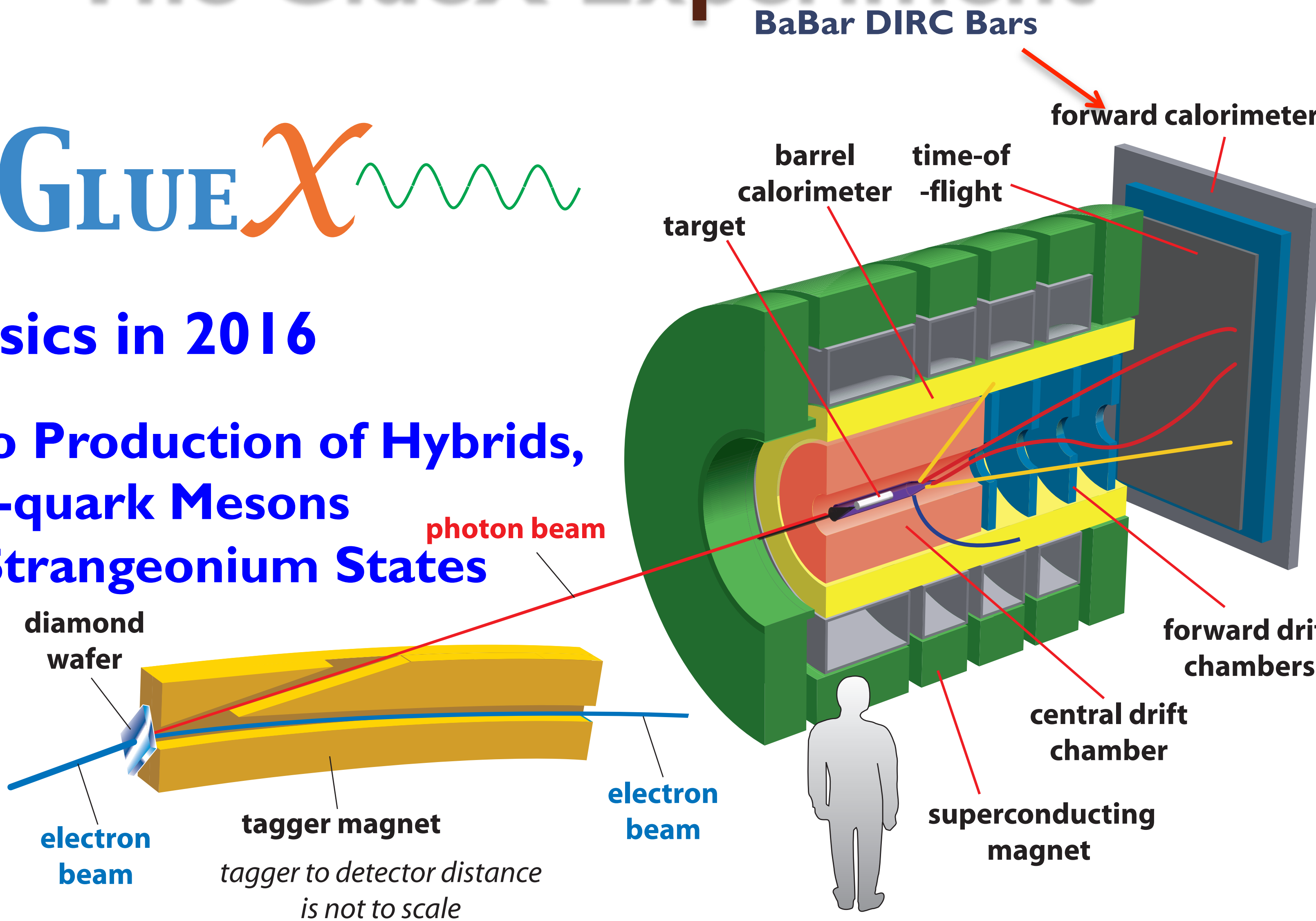


The GlueX Experiment

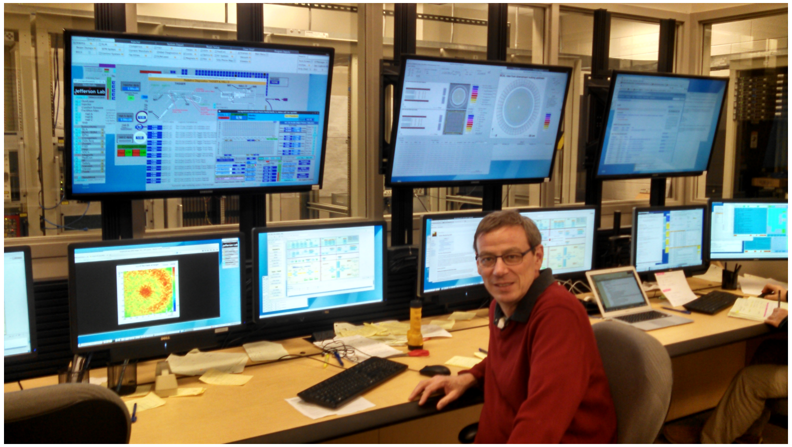
GlueX

Physics in 2016

Photo Production of Hybrids, Light-quark Mesons and Strangeonium States



GlueX Commissioning Runs



- Late October to mid December 2014 with 10 GeV electrons. No polarized photons, and solid GlueX targets.
- All systems worked, all detectors recorded data using multiple triggers. 120TB of data collected, 930M events.

- April 2015 ran for a few days with 6GeV electrons producing linearly-polarized photons on the liquid-hydrogen GlueX target.
- Better DAQ and triggering led to higher-quality data. 74TB of data collected, 1285M events.
- Many detector systems at design specs, all detector systems are within 30% of design specs.
- Data are fully processed every two weeks. We are extracting physics from GlueX.

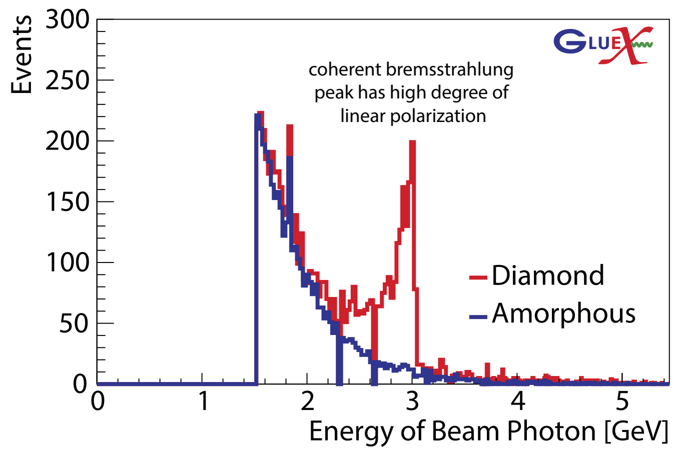
Polarization transfer to the ρ

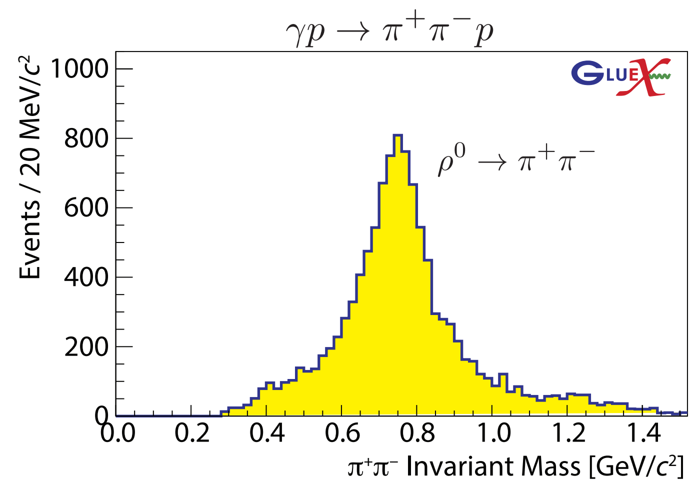
$$\frac{d\sigma}{d\psi} \propto (1 + P\Sigma\cos 2\psi)$$

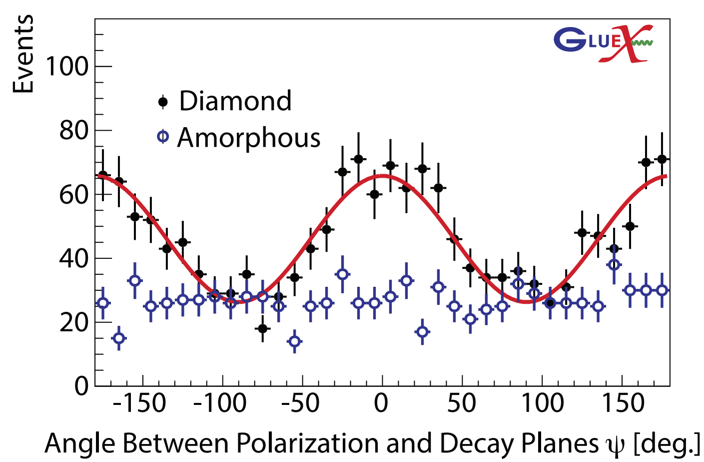
P=Linear Polarization

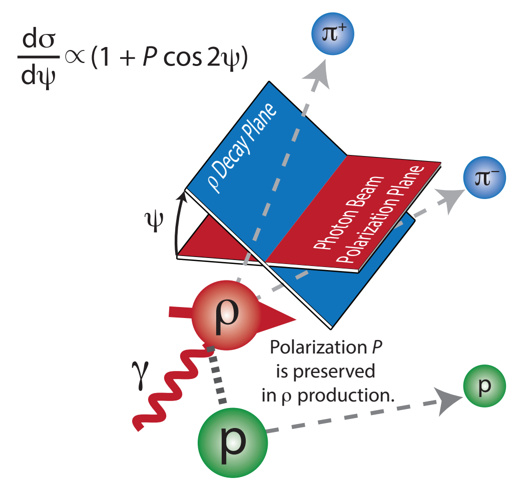
Σ=Beam Asymmetry~1.0

A few hours of beam

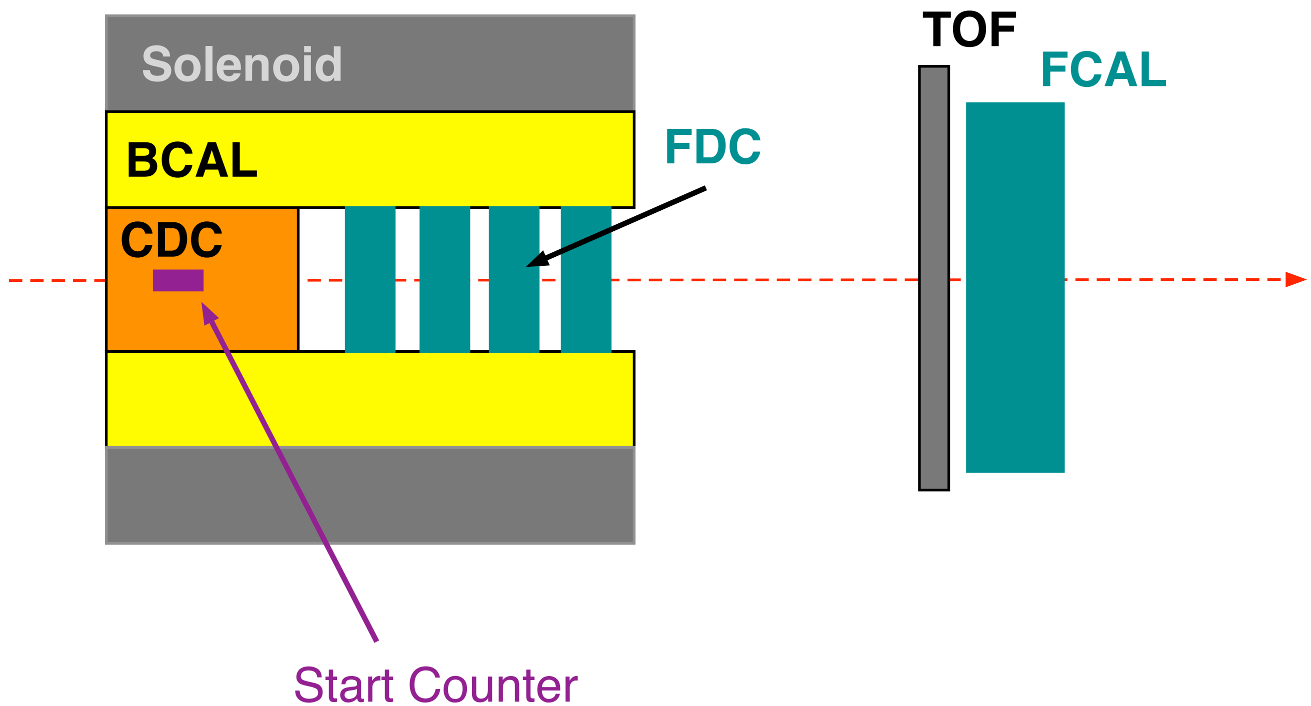








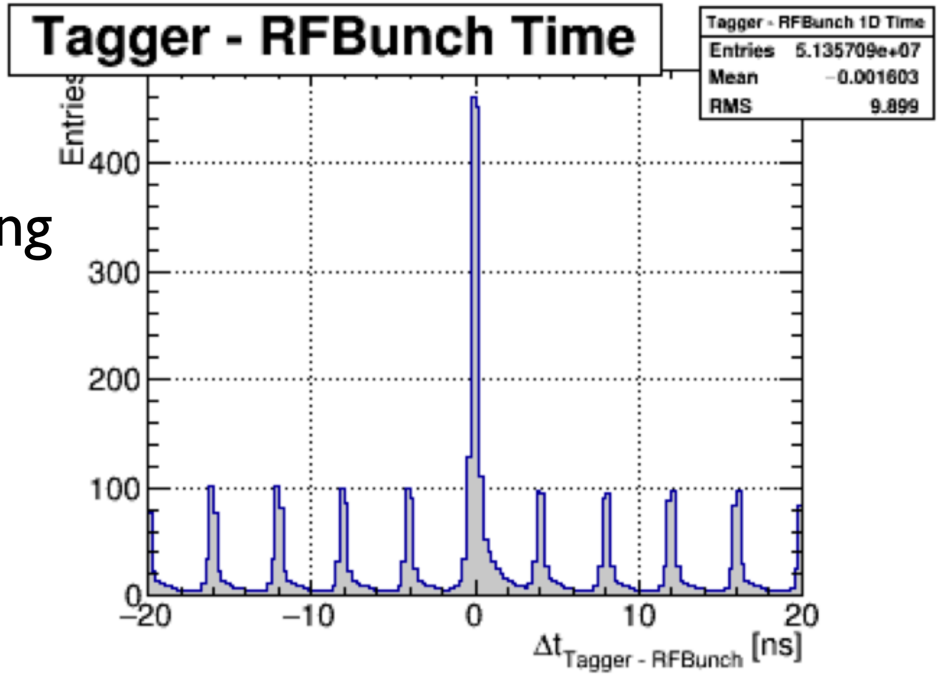
Detector Systems for PID

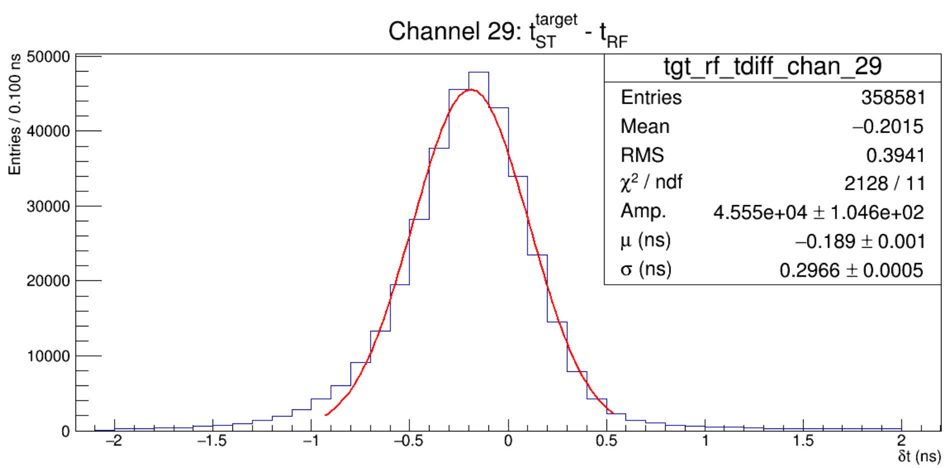


- Start counter, RF timing and TOF/BCAL provide flight times.
- CDC & FDC provide track path lengths and momentum.
- CDC & FDC provide dE/dx information.
- FCAL provides E/p data.

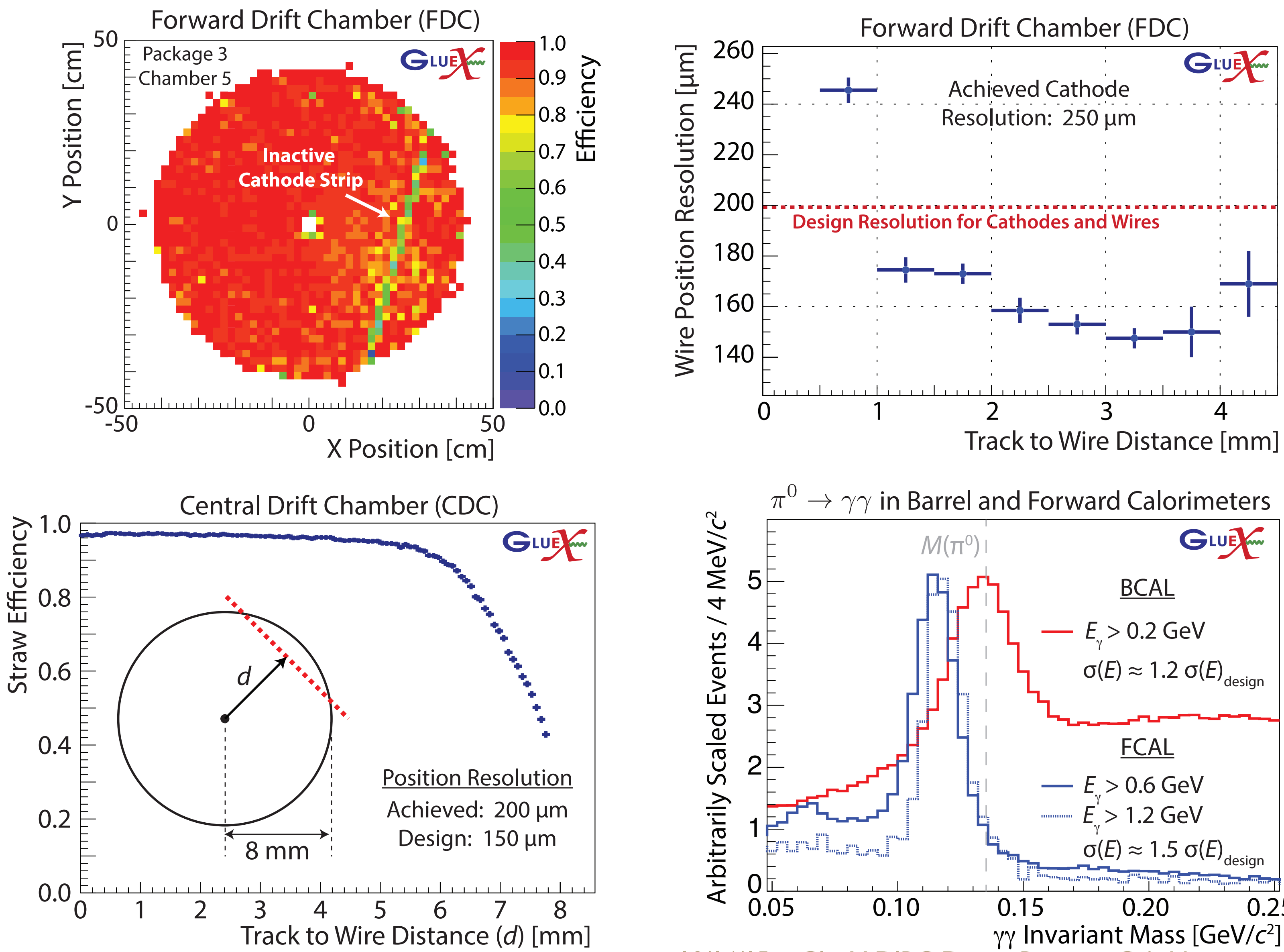
Timing Calibrations

- Electron bunches every ~4 ns
- Accelerator provides RF time
- Select "correct" RF bunch using tracks matched fast timing detectors
  - Start Counter $\sigma_t \approx 300$ ps better than design goal!

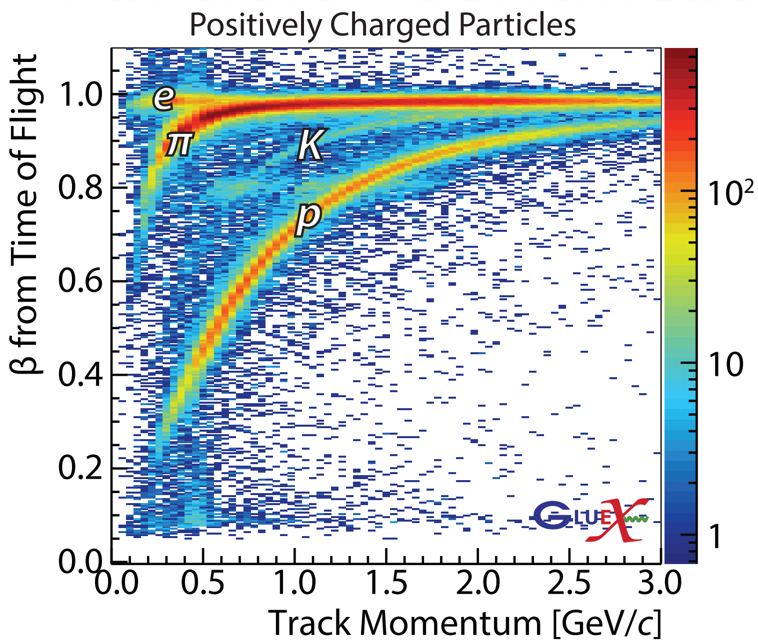


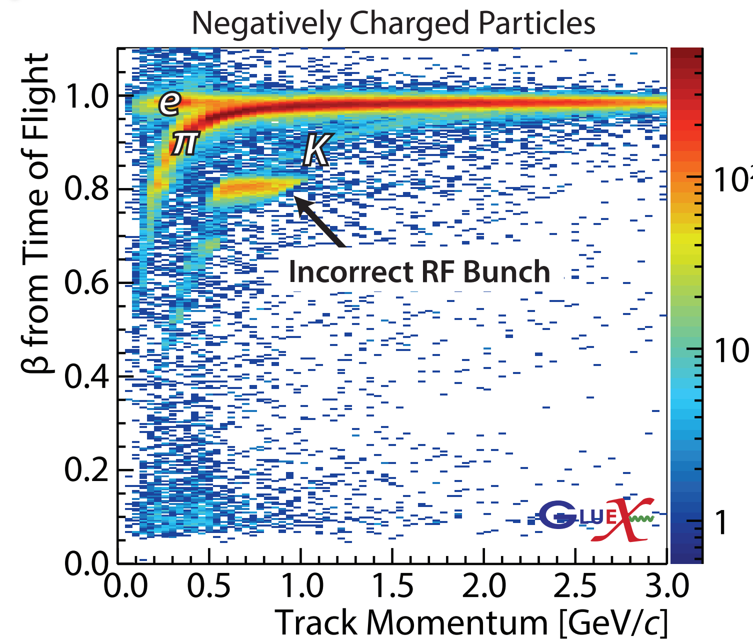


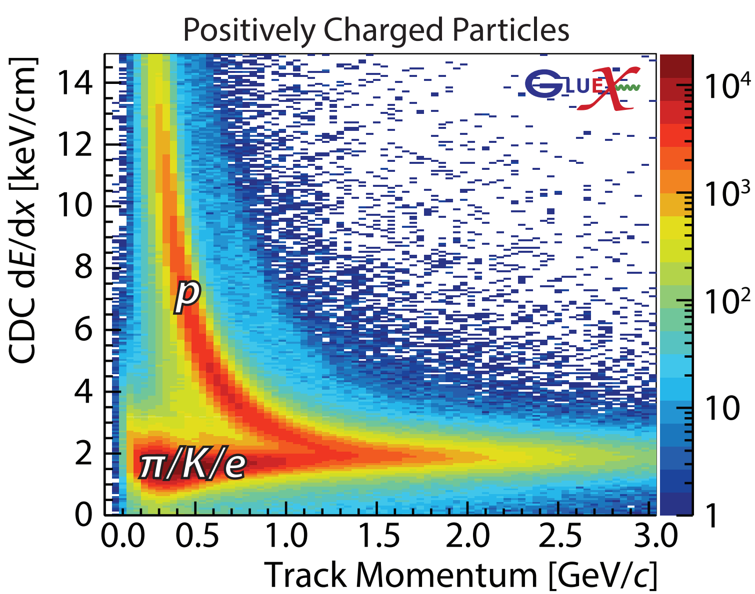
Tracking and Calorimeter Performance

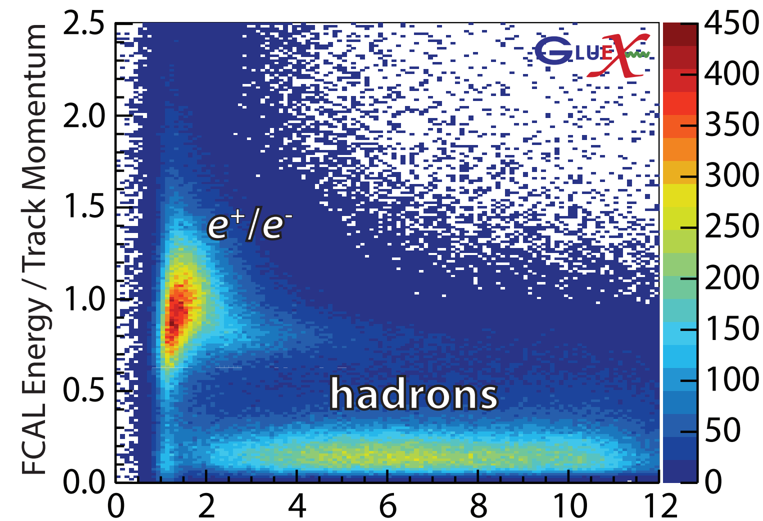


Particle Identification







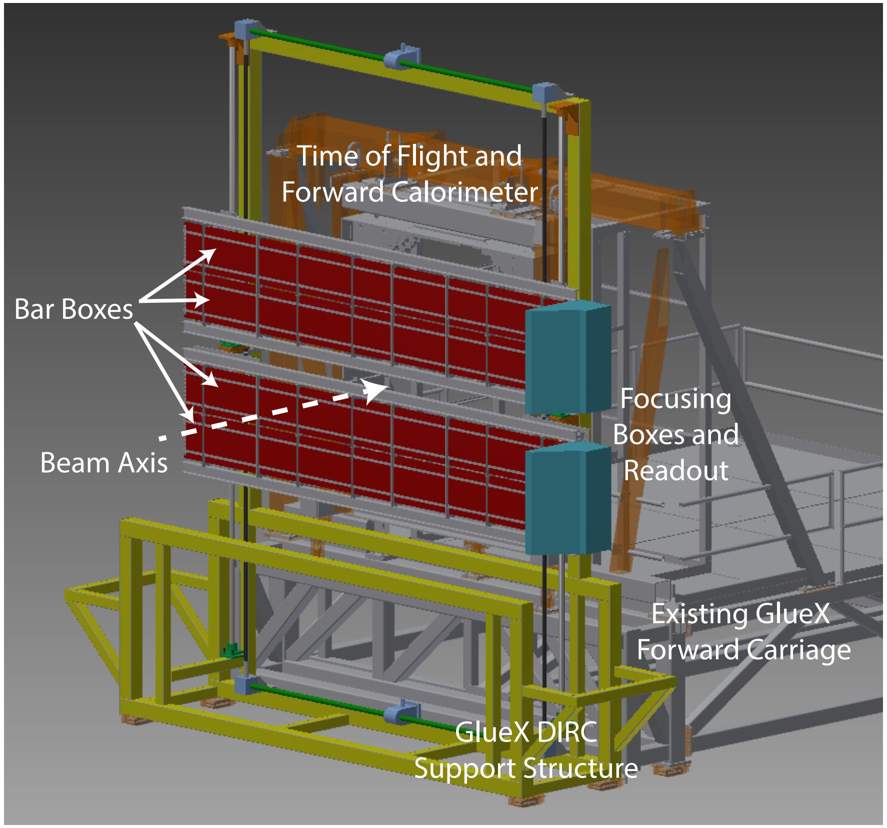


Forward Kaon Identification

- Decays of mesons to kaonic final states are necessary to map out the nonet structure of any found states.
- KK to $\pi\pi$ decay ratios measure the flavor content of mesons.
- Cascade and hyperon baryons are a key part of the GlueX program. Good kaon identification is needed to fully carry out this program.
- The normal strangeonium spectrum is also of interest, especially given the XYZ states in charm.

Forward Kaon Identification

- Four of the BaBar DIRC bar boxes will be installed in front of the TOF wall.
- This combined with the other PID systems in GlueX will allow us to fully study final states with strange quarks.
- Strangeonium mesons and hybrids can be studied.
- Hyperon and cascade baryons can be studied.

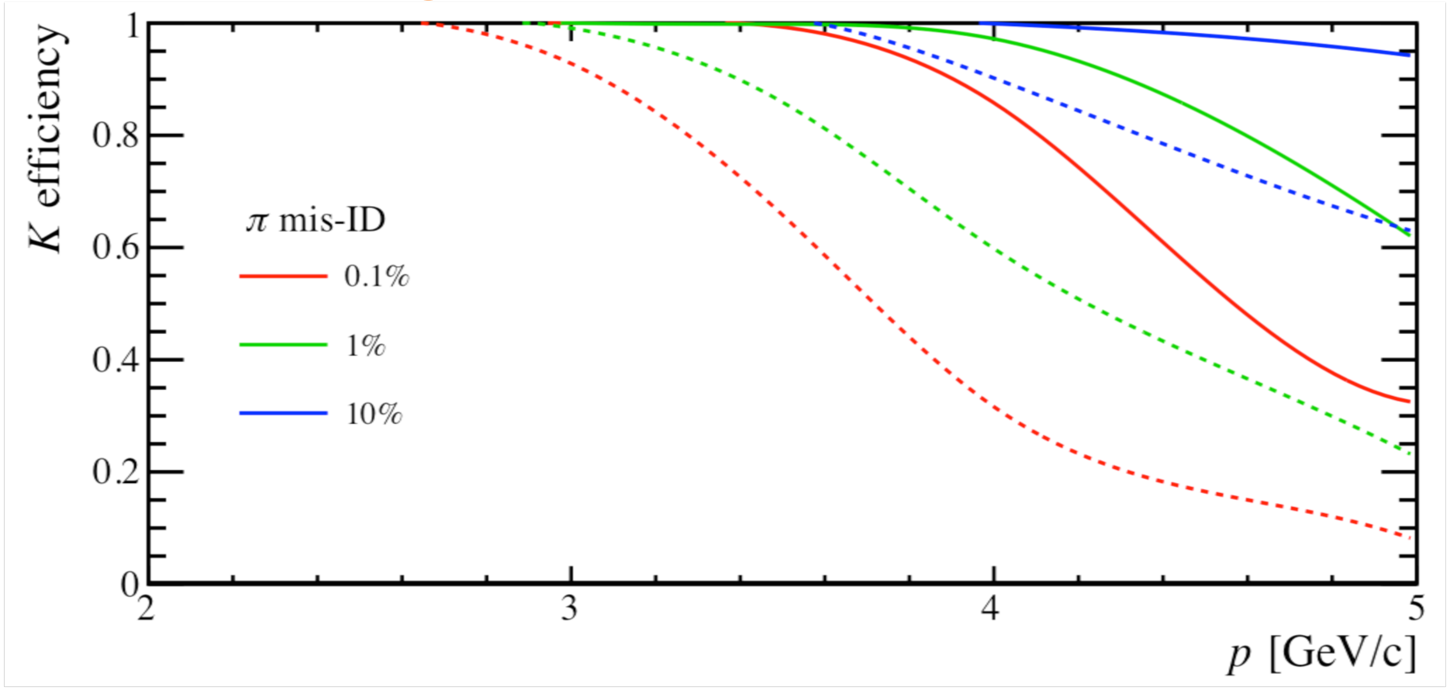


Expected late 2017/ 2018

DIRC Performance

Kaon efficiency as a function of momentum for three different pion misidentification fractions.

- Dashed curves use 2.5mrad resolution assumed in PAC proposal and achieved by BaBar.
- Solid curves show performance achieved by current design simulations.



Decay Modes of Exotic Hybrids

$\pi_1 \rightarrow \pi\rho, \pi b_1, \pi f_1, \pi\eta', \eta a_1$

$\eta_1 \rightarrow \eta f_2, a_2\pi, \eta f_1, \eta\eta', \pi(1300)\pi, a_1\pi,$

$\eta_1' \rightarrow K^*K, K_1(1270)K, K_1(1410)K, \eta\eta'$

$b_2 \rightarrow \omega\pi, a_2\pi, \rho\eta, f_1\rho, a_1\pi, h_1\pi, b_1\eta$

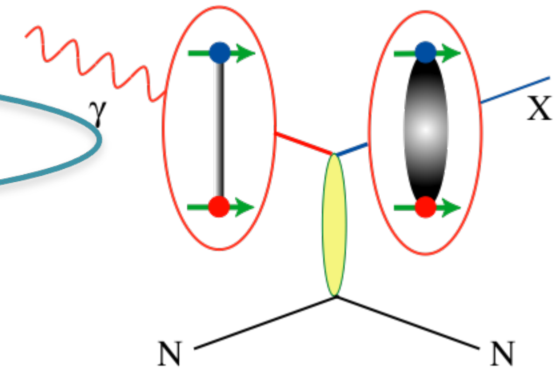
$h_2 \rightarrow \rho\pi, b_1\pi, \omega\eta, f_1\omega$

$h'_2 \rightarrow K_1(1270)K, K_1(1410)K, K_2^*K, \phi\eta, f_1\phi$

$b_0 \rightarrow \pi(1300)\pi, h_1\pi, f_1\rho, b_1\eta$

$h_0 \rightarrow b_1\pi, h_1\eta$

$h'_0 \rightarrow K_1(1270)K, K(1460)K, h_1\eta$

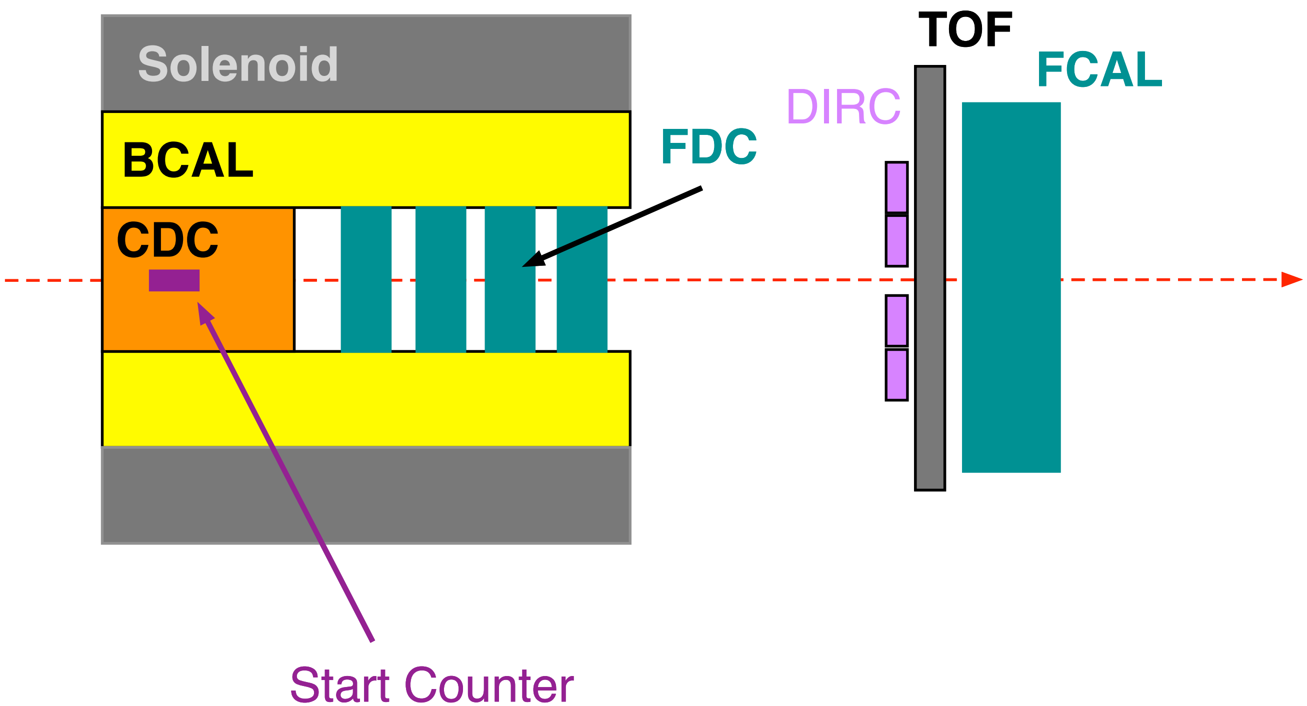


Early Reach **With Statistics** **Hard**

Models suggest narrower states are in the spin-1 and spin-2 nonets, while the spin-0 nonets are broad.

Hybrid kaons do not have exotic QN's

Detector Systems for PID



- Baseline GlueX provides K/p separation up to about 2 GeV/c.
- The addition of the DIRC pushes this up to 4.5 GeV/c.
- Global analysis of event is used, so we are not limited by one piece of information.

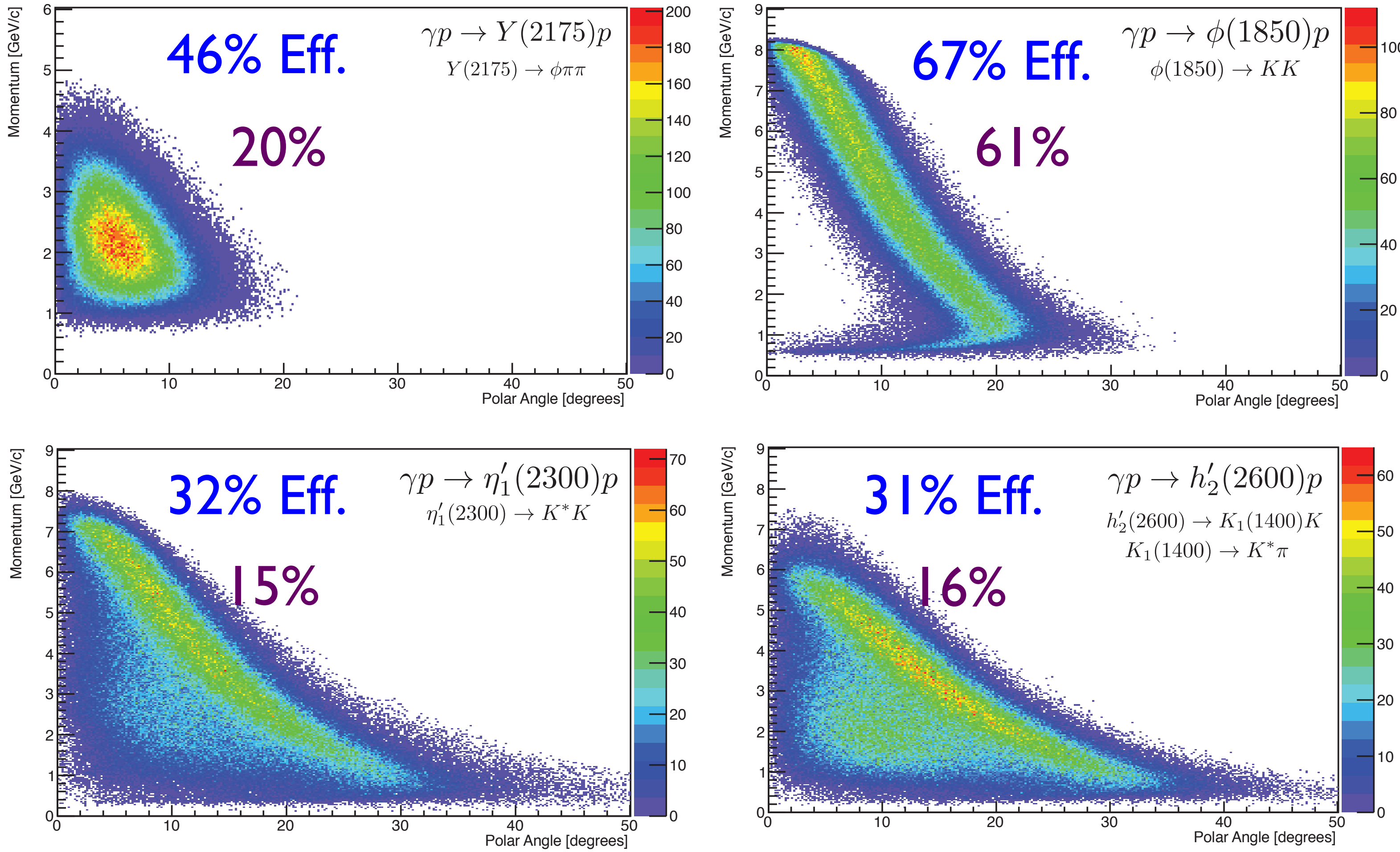
DIRC Performance

- Global event-identification schemes.
  $$\gamma p \to p h_2' \to p K_1 K \to p K^+ K^- \pi^+ \pi^-$$
- Exclusive final state, 4C-kinematic fitting possible.
- Globally examine all variables that can classify the event: KinFit Prob., Individual detector PID information, topology information, ….
- Use machine-learning tools to develop a classifier. For GlueX, we have been using a Boosted Decision Tree (BDT).
- Optimize on purity and efficiency.

DIRC Performance

- Using Amplitude Analysis, we expect to be able to decompose a sample of events from a given final state into a coherent sum of partial waves.
- Partial waves can be interpreted in terms of particles, and lead to identification of exotic hybrids.
- The technique sensitivity is (approximately) limited by the level of the background. 99% purity, lets us access physics details that are not possible to study with 90% purity.

Global Particle Identification

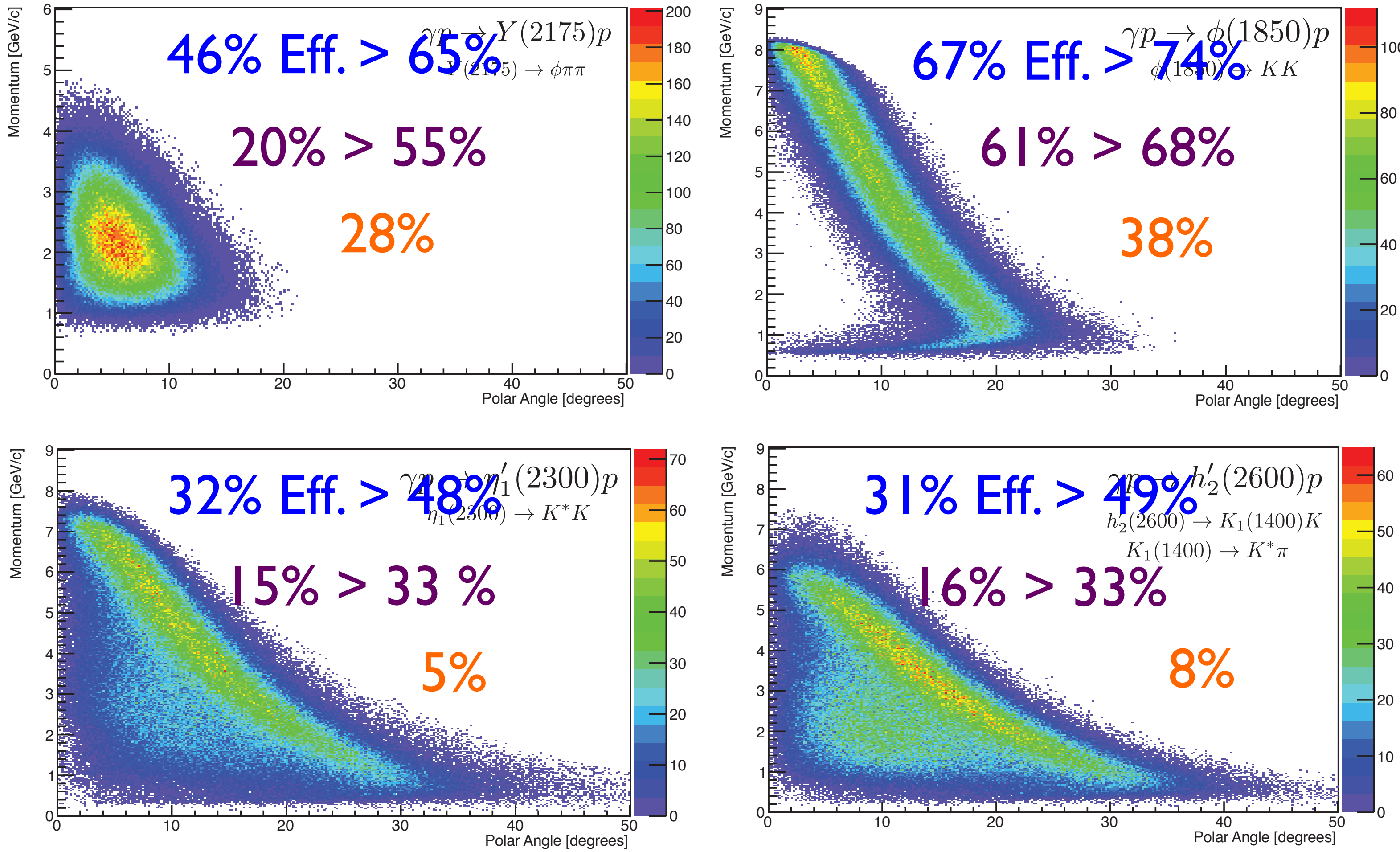


Request 90% purity in the event sample.

Request 95% purity in the event sample.

The baseline GlueX detector can provide pure kaonic event samples with good efficiency.

Global Particle Identification



Request 90% purity in the event sample.

Request 95% purity in the event sample.

Request 99% purity in the event sample.

The DIRC will significantly kaon identification and enable the full GlueX Physics program.

JLab PAC Approval

- The Jefferson Lab PAC has given an A rating to the physics program of GlueX including parts of the BaBar DIRC as a forward kaon-identification system.

Recommendation: Approve

GlueX is the flagship experiment in Hall D; the physics motivation for the proposed running is very sound. The motivation for the hardware extension is very obvious to reach the physics goals of the experiment and is strongly supported by the PAC.

Project Overview

- GlueX will receive 4 BaBar DIRC boxes.
- GlueX plans to use the CLAS-RICH readout and electronics.

Key Tasks for GlueX

- Transportation of DIRC boxes to JLab.
- Designing Focusing Box for GlueX.
- Instrumentation and integration of the detector readout.
- Design frame and the installation of the detector in GlueX.
- Getting the physics out of the DIRC.

Project Overview

- Project profile allows us to install ½ of the system in summer 2017, and remainder in summer 2018.
- The early installation of ½ of the system allows for early integration of the DIRC into GlueX simulation and analyses with realistic performance numbers.
- Sufficient manpower from MIT, IU, JLAB and GSI is associated with the project to complete it on schedule.

Summary

- GlueX is installed and well into its commissioning with all detector systems are approaching design specifications in performance.
- The DIRC-based kaon identification system is needed to carry out the full GlueX physics program.
- The 2.5mrad resolution achieved by BaBar is sufficient for GlueX Physics needs. Current simulations suggest that we can do better than this in the GlueX geometry.
- The DIRC timeline is consistent with the broader physics goals of the experiment and provides an opportunity for early integration.

The GlueX Collaboration

Arizona State, Athens, Carnegie Mellon, Catholic University, Univ. of Connecticut, Florida International, Florida State, George Washington, Glasgow, Indiana University, ITEP, Jefferson Lab, U. Mass Amherst, MIT, MePhi, Norfolk State, North Carolina A&T, Univ. North Carolina Wilmington, Northwestern, Santa Maria, University of Regina and Yerevan Physics Institute.

Over 100 collaborators from 22 institutions. Others planning to join over the next 6 months and more are welcome.

Experiments using GlueX

GlueX—Hybrid mesons/spectroscopy PR-06-102, PR-12-002 & PR-13-003	A rating 340-540 PAC days
GlueX—PrimEx-eta PR-10-011 (calorimeter plug)	A- rating 79 PAC Days
GlueX—Pion polarizability PR-13-008 (forward muon detector)	A- rating 25 PAC Days
GlueX—JEF: Rare eta decays PR14-004 (calorimeter upgrade)	Conditionally Approved